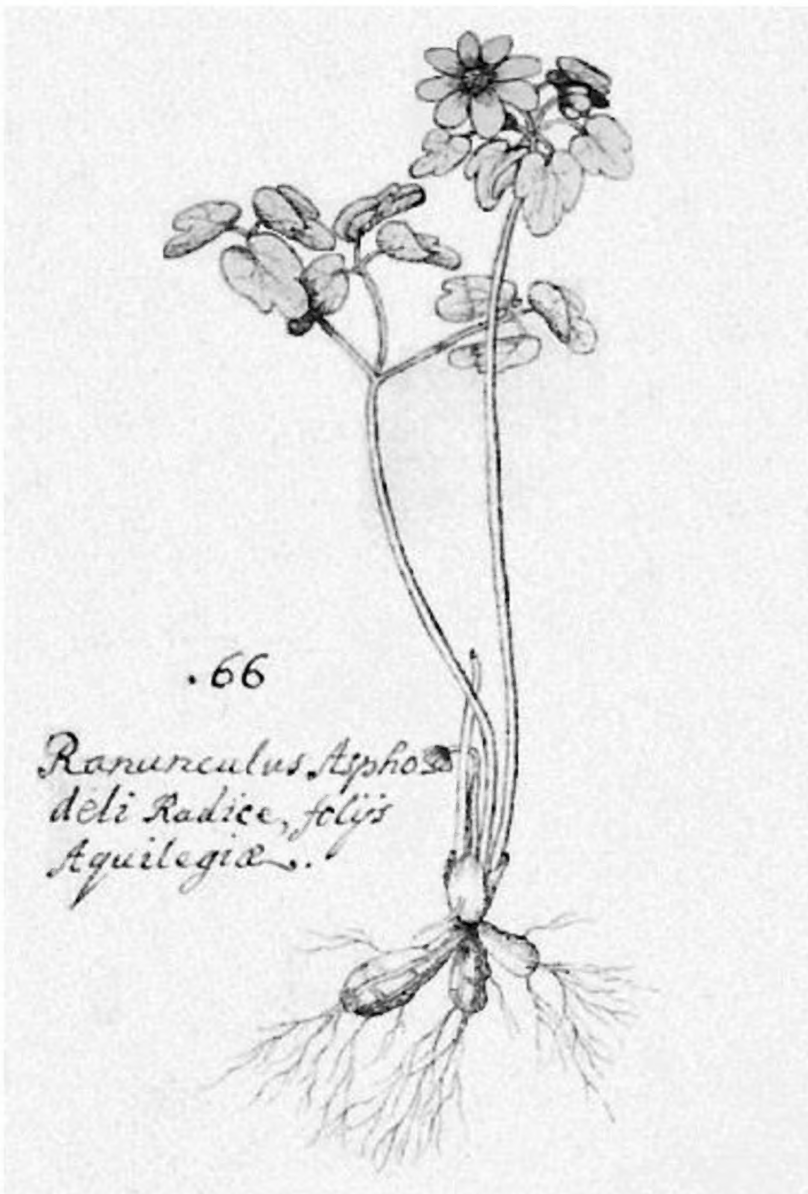
BANISTERIA

A JOURNAL DEVOTED TO THE NATURAL HISTORY OF VIRGINIA



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Cover: *Thalictrum thalictroides* (L.) Eames & Boivin (Rue-anemone)
Back cover: *Lonicera sempervirens* L. (Trumpet or Coral Honeysuckle)

Original drawings by John Banister, sent to Bishop D. H. Compton in 1689. Figures 73 and 91, respectively, in folio in Sir Hans Sloane's MS 4002 in the British Museum. Photocopies courtesy of Joseph and Nesta Ewan.

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Number 49, 2017

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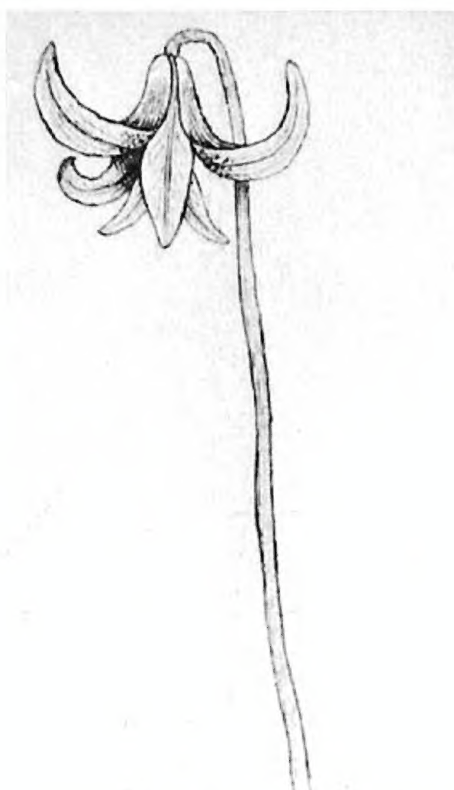
Miscellanea



Lilium sp.; original drawing by John Banister

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Biotic Condition and Species Composition of the Fish Community of Big Moccasin Creek, Scott and Russell Counties, Virginia

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ABSTRACT

We analyzed species composition and index of biotic integrity (IBI) of the fish assemblages of Big Moccasin Creek (BMC), Scott and Russell counties, Virginia. A total of 11,933 individuals representing 36 species was collected at 10 sites. Largescale Stoneroller (*Campostoma oligolepis*), Tennessee Shiner (*Notropis leuciodus*), and Warpaint Shiner (*Luxilus coccogenis*) were the most abundant species. Two previously known but rare species, Stonecat (*Noturus flavus*) and Blotchside Logperch (*Percina burtoni*), were found to be extant in the system. IBI scores ranged from 40 (fair) to 50 (good). With the exception of the uppermost station, the highest scores were found in the lower half of the creek. Our survey indicates that BMC is mostly in fair condition, which indicates a loss in species richness, skewed trophic structure, and lack of top carnivores. Additional restoration efforts need to be focused on this system to protect and restore its ecological health.

Key words: fish assemblage, index of biotic integrity, endemic, Holston, restoration.

INTRODUCTION

As part of the Tennessee River Basin, the Holston River originates in southwestern Virginia from three headwater tributaries - the North, Middle, and South Forks. Among these, the North Fork Holston River (NFHR) is the longest and historically supported the highest fish diversity with over 72 species. In the late 19th and early 20th centuries, industrial-related chemical spills in the upper reaches resulted in catastrophic fish kills downstream (Jenkins & Burkhead, 1994). Although there are currently less than 64 fish species known from the NFHR in Virginia, this loss could have been even greater if it were not for larger tributaries that provided unpolluted refugia during these events (Jenkins & Burkhead, 1994). Of the few, large feeders within the NFHR drainage, Big Moccasin Creek (BMC), a warm-water stream that enters at the lower section of the river, could have served this purpose. BMC is known to contain 42 native and two introduced fish species (VDGIF FWIS, 2016). Additionally, it has one of the few populations of Stonecat (*Noturus flavus*) in the NFHR drainage, and supports a relict population of Blotchside Logperch (*Percina burtoni*), a rare endemic darter.

Index of biotic integrity (IBI) monitoring is a standard methodology to assess the environmental quality of rivers and streams using structural and functional characteristics of the fish communities (Lyons, 1992). IBI can be used to assess long-term changes in the health of a river body because it is sensitive to water quality and physical habitat disturbances (Karr et al., 1986). It uses multiple metrics that reflect a range of relationships to environmental factors. Each metric is scored 1-poor, 3-intermediate, or 5-good depending on how it compares to a component of a minimally-disturbed reference fish community within

the same ecoregion and similar drainage area (Karr et al., 1986). Although no single metric can be used to determine overall stream health, they can be used individually to interpret and explain results (Plafkin et al., 1989). The final score is determined by tallying all metrics to indicate the level of stream ecological health. The integrity classes include: 60-58 (Excellent), 52-48 (Good), 44-40 (Fair), 34-28 (Poor), and 22-12 (Very Poor).

The Tennessee Valley Authority (TVA) has been monitoring streams and rivers using IBI techniques in the Upper Tennessee drainage since the early 1990s (Matthews & Malone, 2016). Their IBI criteria are developed by the Tennessee Department of Health and Environmental Conservation [TDHEC] (1996), which are specifically applicable to the Upper Tennessee River drainage. The results of TVA's IBI assessment indicate BMC is an impaired system; however, this is based on sporadic and limited sampling. Between 1994 and 2007, TVA sampled four sites of which only one was sampled for more than two years. Their most consistently sampled site was at river kilometer (RKm) 6.1, which was visited in 1994, 1997, 2002, and 2007. Total IBI scores averaged 42 (fair), with a low of 38 (poor/fair) in 1997 and a high of 46 (fair/good) in 2002. The lowest scored metrics during this period were related to a decrease in sunfish, suckers, and piscivores and an increase in omnivores. These low ratings may indicate impairment to the fish community due to sedimentation in the form of siltation and excessive nutrients. Possible sources of these impairments in the BMC watershed include cattle production, forestry, and urban development.

Our main objective was to use IBI methodology to assess BMC by sampling multiple sites over one field season. The secondary objective was to provide a cursory examination of the fish distribution and composition of BMC. Information gathered would be useful as a baseline reference of stream health and for the evaluation of future restoration efforts.

MATERIALS AND METHODS

Study Area

BMC originates at Hansonville, Russell County, Virginia, and flows southwest for 88 km between Moccasin Ridge to the north and Clinch Mountain to the south before emptying into the North Fork Holston River upstream of Weber City, Scott County, Virginia. The watershed area of BMC is 245.45 km^2, which is approximately 14% of the total NFHR basin. The entire BMC watershed is within the Ridge and Valley Physiographic Province and is comprised of limestone, dolomites, and shales in the lowlands and sandstones on the mountains. Land use is 54% forest, 37% agriculture, and 7% residential (Wickham et al., 2014). The remaining 2% is open water and wetlands. Agriculture, in the form of pasture and row crops, is mostly confined to the valley and along the mainstem. Most of the mountainous regions are forested, while the residential areas are concentrated in Gate City and Weber City, Scott County, in the lower 5 km of BMC.

Fish Sampling

We sampled a total of 10 sites at base-flow conditions between 14 July and 16 September 2009 (Fig. 1; Table 1). Sites were primarily selected to be an equal distance apart from each other between the mouth and the headwaters. In order to collect representative fish diversity at each site, locations were adjusted to ensure the presence of multiple meso-habitats (i.e., pools, riffles, and runs). Landowner permission was the final criterion for site selection. The average distance between sites was 9.4 km (± 0.85 SE).

We used standardized TVA methods for conducting IBI fish sampling. For riffles and runs, we used a Smith-Root gas-powered SR-24 backpack unit and seine net (1.5 m x 3 m). Most sampling occurred 3 m upstream of the seine net that was placed perpendicular to stream flow forming a 9 m^2 quadrat. If needed, quadrat size was adjusted and noted for smaller habitat areas. Quadrats were placed at the downstream end of the habitat unit and subsequent quadrats were adjacent to or upstream of the previous sample. No quadrat was sampled more than once and the number of quadrats sampled at any particular habitat unit was a function of its size. Once a habitat was completely covered, we would move upstream to find and sample the same habitat type. While turning over substrate to dislodge benthic species, fish were collected in a single pass that covered the entire quadrat.

The goal of the TVA sampling design was to maximize fish species richness by rigorously sampling all available habitats. Three quadrats were sampled in each habitat type. If an additional species was collected, we would reset our sampling effort to zero and three additional quadrats would be sampled in the same habitat type. We would continue sampling using this technique until no additional species were found in each habitat type. Except for shoreline sampling, this method does not have a predetermined distance but is extremely intensive ensuring most habitats and fish species are represented in the sample. In all fish sampling techniques (electrofishing, seine hauling, and shoreline), fish species were identified, counted, and recorded before being released downstream of each quadrat. Fish were

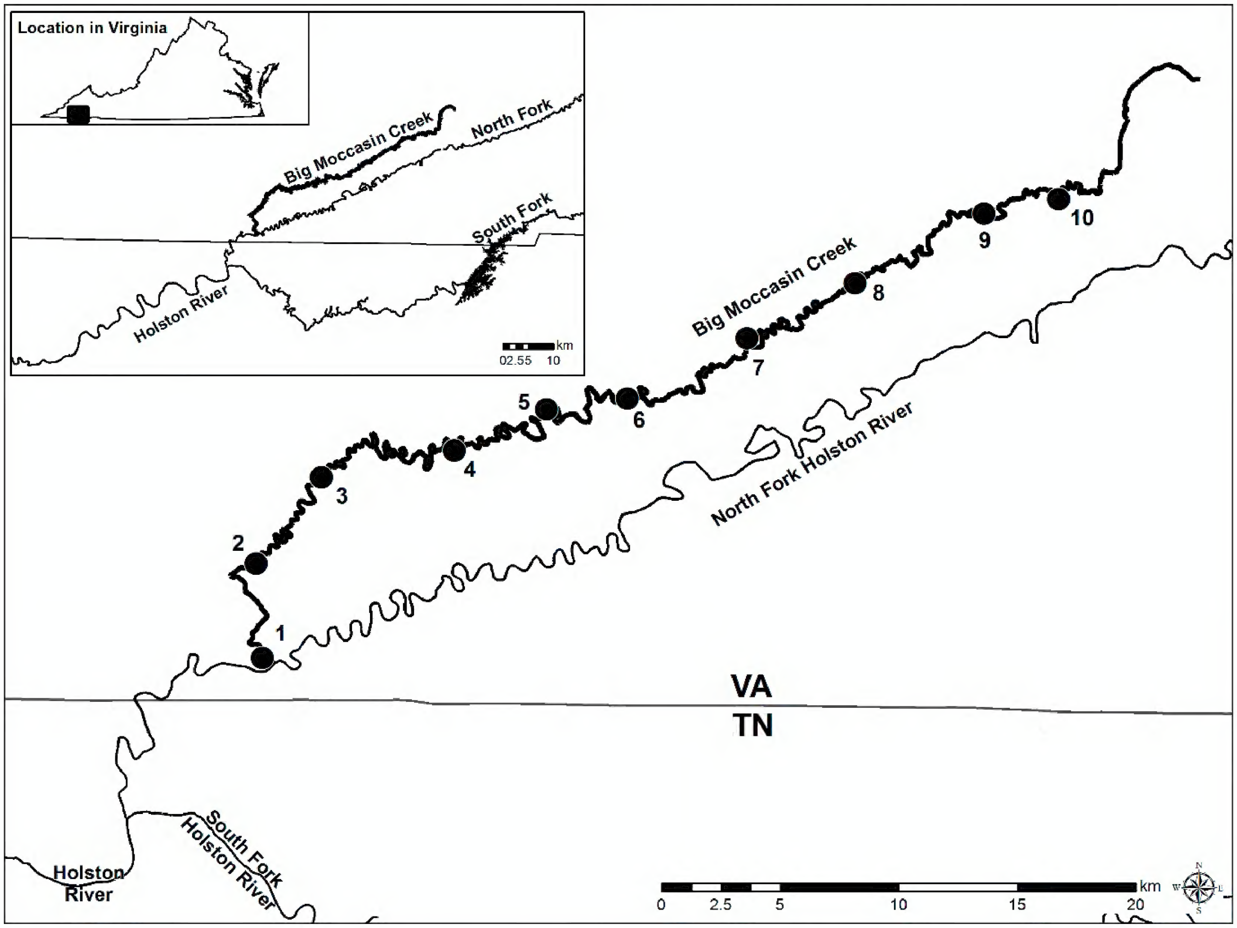

Fig. 1. Fish sampling sites on Big Moccasin Creek, Scott and Russell counties, Virginia.

also noted for disease, parasites, and hybridization. As a result of capture inefficacy and difficulty in identification, fish less than 20 mm were considered young of year and were not recorded (Karr et al., 1986).

Seine hauling was used to sample low velocity habitats such as pools, deep runs, and backwaters. The area of each quadrat sampled was determined by the length of the seine net and the distance it was hauled. Two individuals pulled an open seine (1.5 m x 3 m) while a third individual followed to free the seine net from obstacles (i.e., logs, rocks, etc.). Each haul was terminated by beaching the seine net on shore or by curling the ends and rapidly lifting it midstream.

Shoreline sampling, which often overlapped the other three habitats, was conducted last. The sample effort for shoreline sampling was 1 m from the bank edge for a distance of 46 m at each site. The beginning point typically started near the lowermost sampled habitat. Shoreline sampling consisted of a minimum of one person electroshocking and another with a dip net moving in an upstream direction to avoid turbidity caused by disturbing the stream bottom. Two 46 m sections were sampled at each site. An additional 46 m reach was sampled if a new species was captured at the site. Voucher specimens are housed at the TVA ichthyological facility, Norris, TN.

Biotic Condition

The IBI is comprised of 12 metrics that are used to reflect fish community structure and function including native species richness, taxonomic composition, trophic structure, pollution tolerance, abundance, and condition (Table 2). Most metrics are scored based on their species/drainage area relationship (Plafkin et al., 1989). The native status and ecological information detailed in Table 3 is derived from Pflieger (1975), Smith (1979), Lee et al. (1980), Etnier & Starnes (1993), and Jenkins & Burkhead (1994).

Table 1. Sampling sites on Big Moccasin Creek, Scott and Russell counties, Virginia.

Site	River Km above confluence	County	Quadrangle	Sample date	Coordinates	Basin area (km^2)
1	0.64	Scott	Kingsport	14 July 2009	36.6111 -82.5497	243.46
2	7.08	Scott	Gate City	14 July 2009	36.6476 -82.5532	206.16
3	15.93	Scott	Gate City	15 July 2009	36.6814 -82.5231	191.14
4	30.58	Scott	Hilton	15 July 2009	36.6926 -82.4605	160.32
5	40.55	Scott	Hilton	16 July 2009	36.7090 -82.4172	148.41
6	48.76	Scott	Hilton	14 Sept 2009	36.7136 -82.3791	135.71
7	58.74	Russell	Mendota	14 Sept 2009	36.7376 -82.3230	108.52
8	68.72	Russell	Moll Creek	15 Sept 2009	36.7595 -82.2723	90.13
9	79.50	Russell	Hansonville	15 Sept 2009	36.7870 -82.2118	68.89
10	85.29	Russell	Hansonville	16 Sept 2009	36.7930 -82.1766	30.04

Table 2. Metrics used in calculating Index of Biotic Integrity for sampling sites on Big Moccasin Creek, Scott and Russell counties, Virginia are based on those developed by Karr (1981) and modified by the Tennessee Department of Health and Environmental Conservation (1996) for the Tennessee River drainage. Scoring criteria for each sampling site is as a function of its drainage area.

Metric	Site	Score 1	Score 3	Score 5
Number of native fish species	1	<15	15-28	>28
	2	<14	14-27	>27
	3	14	14-26	>26
	4-5	<13	13-25	>25
	6	<13	13-24	>24
	7	<12	12-23	>23
	8	<12	12-22	>22
	9	<11	11-20	>20
	10	<9	9-16	>16
Number of native darter species	1-3	<3	3-4	>4
	4-5	<2	2-4	>4
	6-9	<2	2-3	>3
	10	<2	2	>2
Number of native sunfish species (less *Micropterus* spp.)	All	<2	2	>2
Number of native sucker species	All	<2	2	>2
Number of intolerant species	1-7	<2	2-3	>3
	8-10	<2	2	>2

Table 2 (continued).

Metric	Site	Score		
		1	3	5
Percentage of tolerant species	1	>27	27-13	<13
	2	>27	27-14	<14
	3	>28	28-14	<14
	4-5	>29	29-14	<14
	6	>29	29-15	<15
	7	>30	30-15	<15
	8	>31	31-16	<16
	9	>32	32-16	<16
	10	>36	36-18	<18
Percentage of individuals as omnivores and stonerollers	1	>30	30-15	<15
	2	>31	31-16	<16
	3	>32	32-16	<16
	4	>33	33-16	<16
	5	>33	33-17	<17
	6	>34	34-18	<18
	7	>35	35-18	<18
	8	>37	37-18	<18
	9	>39	39-19	<19
	10	>44	44-22	<22
Percentage of individuals as specialized insectivores	1	<25	25-50	>50
	2	<24	24-48	>48
	3	24	24-47	47
	4	23	23-46	46
	5	<23	23-45	>45
	6	<22	22-43	>43
	7	<21	21-42	>42
	8	<20	20-41	>41
	9	<19	19-39	>39
	10	<16	16-31	>31
Percentage of individuals as piscivores	All	<2	2-4	>4
Percentage of individuals as hybrids	All	>1	1-0	<0
Percentage of individual species with disease, tumors, fin damage, and other anomalies	All	>5	5-2	<2
Catch rate (average number of fish/300 ft^2 [28.7 m^2]) sampling unit	1	<15	15-29	>29
	2	<15	15-31	>31
	3	<16	16-31	>31
	4	<16	16-33	>33
	5	<17	17-33	>33
	6	<18	18-36	>36
	7	<18	18-36	>36
	8	<19	19-38	>38
	9	<21	21-41	>41
	10	<26	26-52	>52

Table 3. Fish species collected in Big Moccasin Creek, Scott and Russell counties, Virginia, with designations for native status, trophic guild, family group, and pollution tolerance for the Tennessee River drainage. Native status and ecological information are presented by Pflieger (1975), Smith (1979), Lee et al. (1980), Etnier & Starnes (1993), and Jenkins & Burkhead (1994).

Scientific name	Native	Trophic guild	Family group	Tolerance
Rhynichthys obtusus	Yes	Specialized Insectivore	Cyprinidae	----
Campostoma oligolepis	Yes	Herbivore	Cyprinidae	----
Nocomis micropogon	Yes	Omnivore	Cyprinidae	----
Phenocobius uranops	Yes	Specialized Insectivore	Cyprinidae	----
Hybopsis amblops	Yes	Specialized Insectivore	Cyprinidae	Intolerant
Cyprinella galactura	Yes	Insectivore	Cyprinidae	----
Cyprinella spiloptera	Yes	Insectivore	Cyprinidae	Tolerant
Luxilus coccogenis	Yes	Specialized Insectivore	Cyprinidae	Intolerant
Luxilus chrysocephalus	Yes	Omnivore	Cyprinidae	Tolerant
Notropis micropteryx	Yes	Specialized Insectivore	Cyprinidae	----
Notropis leuciodus	Yes	Specialized Insectivore	Cyprinidae	Intolerant
Notropis photogenis	Yes	Specialized Insectivore	Cyprinidae	----
Notropis telescopus	Yes	Specialized Insectivore	Cyprinidae	Intolerant
Notropis volucellus	Yes	Specialized Insectivore	Cyprinidae	----
Notropis sp.	Yes	Specialized Insectivore	Cyprinidae	----
Pimephales notatus	Yes	Omnivore	Cyprinidae	----
Hypentelium nigricans	Yes	Insectivore	Catostomidae	Intolerant
Catostomus commersoni	Yes	Omnivore	Catostomidae	Tolerant
Moxostoma duquesnei	Yes	Insectivore	Catostomidae	Intolerant
Moxostoma erythrurum	Yes	Insectivore	Catostomidae	----
Ameiurus natalis	Yes	Omnivore	Ictaluridae	Tolerant
Noturus flavus	Yes	Insectivore	Ictaluridae	----
Cottus baileyi	Yes	Insectivore	Cottidae	----
Cottus carolinae	Yes	Insectivore	Cottidae	----
Ambloplites rupestris	Yes	Piscivore	Centrarchidae	Intolerant
Micropterus dolomieu	Yes	Piscivore	Centrarchidae	----
MIcropterus salmoides	Yes	Piscivore	Centrarchidae	----
Lepomis auritus	No	Insectivore	Centrarchidae	----
Lepomis megalotis	Yes	Insectivore	Centrarchidae	----
Lepomis macrochirus	Yes	Insectivore	Centrarchidae	----
Percina burtoni	Yes	Specialized Insectivore	Percidae	----
Etheostoma simoterum	Yes	Specialized Insectivore	Percidae	----
Etheostoma blennioides	Yes	Specialized Insectivore	Percidae	----
Etheostoma zonale	Yes	Specialized Insectivore	Percidae	----
Etheostoma rufilineatum	Yes	Specialized Insectivore	Percidae	----
Etheostoma flabellare	Yes	Specialized Insectivore	Percidae	Intolerant

Species richness and composition metrics includes number of darter, sunfish, sucker, and intolerant species and percentage of tolerant species. Darter and sucker species are sensitive to degradation in benthic habitats where they feed and spawn. Similarly, sunfish are sensitive to impacts in pools and the lack of instream cover (Karr et al., 1986). Tolerance is related to a species' susceptibility to siltation, low dissolved oxygen, and toxins (Karr et al., 1986). In streams impacted by chemical and physical degradation, darter, sunfish, sucker, and intolerant species will decrease in number. In contrast, tolerant species, such as Green Sunfish (*Lepomis cyanellus*) and Creek Chub (*Semotilus atromaculatus*), will increase and can become dominant in disturbed systems (Plafkin et al., 1989).

Trophic structure is based on adult feeding patterns

such as herbivores, omnivores, insectivores, and piscivores (Karr et al., 1986). The TDHEC (1996) metric "Percentage of individuals as omnivores and stonerollers" is a variation from Karr et al. (1986) that uses "Proportion of individuals as omnivores." Owing to their varied diet of plants and animals, omnivores are tolerant to changes in their food base caused by environmental degradation (Lyons, 1992). Stonerollers (*Campostoma* spp.) are primarily herbivores feeding on algae and sometimes detritus (Jenkins & Burkhead, 1994). A disproportionately high abundance of stonerollers in the fish community can be an indicator of elevated algae growth caused by increased nutrients in a system (TDHEC, 1996). The TDHEC (1996) metric "Percentage of individuals as specialized insectivores" is a variation from the Karr et al. (1986) metric "Proportion of individuals as insectivorous cyprinids." Specialized insectivores, including both cyprinids and darters, respond negatively to a decrease in their invertebrate food sources because of habitat degradation (Plafkin et al., 1989). The "Percentage of individuals as piscivores" metric represents top carnivores that feed on fish and crayfish (Karr et al., 1986). These species will decline as habitat degrades, which in turn impacts their food source.

The "Catch rate" metric or as defined by Karr et al. (1986) "Number of individuals in a sample" is used to evaluate population abundance. The TDHEC (1996) metric uses number of fish/300 ft^2 or 28.7 m^2. Depending on the region and stream size, density of individuals is expected to decline as integrity decreases (Plafkin et al., 1989).

Fish condition metrics are determined by individuals that are hybrids and those with disease and other anomalies within the fish community. Karr et al. (1989) indicate that hybridization can increase in degraded systems, a result of altered reproductive isolation among species. Hybrids can be difficult to detect, especially for minnows and darters (Karr et al., 1986). Fish exhibiting an excessive amount of diseases, parasites, fin damage, and other anomalies can be indicative of environmental degradation. The most frequent and easily observed parasite in these systems is a trematode (*Neascus* sp.) infection that appears as black spots on the fins and body (Post, 1987). TVA IBI assessment protocols require more than five spots on an individual fish to have a disease diagnosis (TDHEC, 1996).

Fish data from each site are pooled and entered separately into Ssurvey, a TVA developed software program. Final data are provided in an Excel Microsoft spreadsheet. Descriptions of each IBI ranking class are detailed in Table 4.

Table 4. Biotic integrity classes used in assessing fish communities along with general descriptions of their attributes (Karr et al., 1986).

Class	Attributes	IBI Range
Excellent	Comparable to the best situations without influence of man; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.	58-60
Good	Species richness somewhat below expectation, especially due to loss of most intolerant forms; some species with less than optimal abundances or size distribution; trophic structure shows some signs of stress.	48-52
Fair	Signs of additional deterioration include fewer intolerant forms, more skewed trophic structure (e.g., increasing frequency of omnivores); older age classes of top predators may be rare.	40-44
Poor	Dominated by omnivores, pollution-tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.	28-34
Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.	12-22
No fish	Repetitive sampling fails to turn up any fish.	

RESULTS

Species Composition and Distribution

A total of 11,933 specimens representing 36 species of six families was captured (Table 5). The most dominant families were Cyprinidae and Percidae with 16 and six species, respectively. The three most abundant species were Largescale Stoneroller (*Campostoma oligolepis*), Tennessee Shiner (*Notropis leucoidus*), and Warpaint Shiner (*Luxilius coccogenis*). The rarest species (three individuals or less) were Stargazing Minnow (*Phenocobius uranops*), Mimic Shiner (*Notropis volucellus*), Golden Redhorse (*Moxostoma erythrurum*), Stonecat (*Noturus flavus*), Longear Sunfish (*Lepomis megalotis*), Bluegill (*L. macrochirus*), and Blotchside Logperch (*Percina burtoni*). All species were native except Redbreast Sunfish (*L. auritus*).

The average number of species per site was 20.8 (range 18-26). Many species were found only at the lowermost station, including Stargazing Minnow, Spotfin Shiner (*Cyprinella splioptera*), Highland Shiner (*Notropis micropteryx*), Sawfin Shiner (*Notropis* sp.), Silver Shiner (*Notropis photogenis*), and Longear Sunfish. The greatest abundance was recorded at Site 8, which was dominated (50%) by Largescale Stoneroller.

Biotic Condition

Metric scores and integrity class for each site are detailed in Table 6. The most frequent metric scores for all sites was “5” (N=65), followed by “3” (N=35) and “1” (N=20). The total scores of individual metrics across all sites ranged from 14 to 50. The highest score of 50 was shared by “Percentage of tolerant species” and “Percentage of individuals as hybrids”, which scored “5” at all sites. The two lowest scores were “Number of native sunfish species” at 14 and “Percentage of individuals as omnivores and stonerollers” at 18. All other metrics ranged between 30 and 46.

IBI site scores averaged 45 (range 40-50). Of the 10 sites sampled, five were ranked “fair” and five as “good.” The “good” sites averaged 48.4 (range 48-50), while “fair” sites averaged 41.6 (range 40-46). Four of the five sites that ranked “good” were located in the lower half of BMC. In contrast, all except one “fair” site were located in the upper half. The metric scores of “5”, “3” and “1” were distributed 37, 16, and 7 for “good” sites and 27, 20, and 13 for “fair” sites, respectively.

In comparing individual metrics between the “good” and “fair” sites, “good” sites had higher scores for “Number of sucker species,” “Percentage of individuals as piscivores,” and “Percentage of individuals with disease, tumors, fin damage, and other anomalies.” There were no differences in “Number of intolerant species” and “Percentage of individuals as specialized insectivores” between sites that scored “good” and “fair.” Only a minimal difference was found between these categories for “Number of darter species.”

DISCUSSION

BMC is mostly in fair condition, which indicates loss in species richness, skewed trophic structure, and lack of top predators (Lyons, 1992). Throughout the creek, omnivores and stonerollers comprised over 45% of the total fish collected indicating a possible impairment to the food base allowing species to flourish that can live on broad diets (Lyons, 1992). Stonerollers alone comprised 32% of the total fish collected and their high abundance may be a result of elevated algal growth, a primary diet component (Jenkins & Burkhead, 1994). Cattle production is the dominant agricultural use in the BMC watershed, and is therefore the most likely source of the nitrogen and phosphorus that contributes to algal growth. The other widespread indicator of stress was the lack of native sunfish species - a possible result of degraded pool habitat and insufficient instream cover (Karr et al., 1986).

Biotic integrity generally decreased from the lower to upper reaches of BMC. The most obvious indicators of impairment in the upper reaches were the loss of suckers and piscivores. Many sucker species are long-lived and their absence may be indicative of chronic chemical and physical habitat degradation (Karr et al., 1986). Piscivores are considered top predators, and thus require a trophically-robust, diverse fish community to sustain their populations (Karr et al., 1986). If this food base is stressed, piscivore numbers will diminish as observed in BMC. Lastly, disease and other anomalies are more prevalent in the upper portions of BMC providing further evidence of an impaired system.

While BMC does show signs of stress, the system is also resilient. In particular, intolerant, specialized insectivores, and darter species had metric scores that indicate they are in good condition. All three metrics include species that are highly sensitive to poor water quality and increases in siltation and turbidity (Karr et al., 1986). Specialized insectivores, which include darters, are indirectly affected by impacts to their food base by the same perturbations (Robertson et al., 2006). The continued presence of these sensitive species may indicate that the degraded conditions in BMC are not beyond recovery.

Table 5. Distribution and abundance of fishes collected in Big Moccasin Creek, Scott and Russell counties, Virginia. Nomenclature follows Page et al. (2013).

		Site										
Common name	Scientific name	1	2	3	4	5	6	7	8	9	10	Total
W. Blacknose Dace	*Rhynichthys obtusus*	-	-	-	-	-	2	-	-	14	48	64
Largescale Stoneroller	*Campostoma oligolepis*	147	19	46	280	225	300	748	814	777	469	3825
River Chub	*Nocomis micropogon*	12	12	59	38	65	70	44	53	32	3	388
Stargazing Minnow	*Phenocobius uranops*	3	-	-	-	-	-	-	-	-	-	3
Bigeye Chub	*Hybopsis amblops*	-	-	-	2	5	11	33	4	41	1	97
Whitetail Shiner	*Cyprinella galactura*	21	11	55	38	36	69	23	28	4	29	314
Spotfin Shiner	*Cyprinella spiloptera*	28	-	-	-	-	-	-	-	-	-	28
Warpaint Shiner	*Luxilus coccogenis*	60	124	186	89	177	152	105	94	60	5	1052
Striped Shiner	*Luxilus chrysocephalus*	47	23	40	157	121	144	93	55	176	135	991
Highland Shiner	*Notropis micropteryx*	10	-	-	-	-	-	-	-	-	-	10
Tennessee Shiner	*Notropis leuciodus*	89	178	173	169	170	271	146	139	273	5	1613
Silver Shiner	*Notropis photogenis*	5	-	-	-	-	-	-	-	-	-	5
Telescope Shiner	*Notropis telescopus*	81	82	42	82	59	162	38	155	147	35	883
Mimic Shiner	*Notropis volucellus*	1	1	-	-	-	-	-	-	-	-	2
Sawfin Shiner	*Notropis sp.*	22	-	-	-	-	-	-	-	-	-	22
Bluntnose Minnnow	*Pimephales notatus*	-	-	-	37	5	7	4	11	21	119	204
Northern Hogsucker	*Hypentelium nigricans*	10	4	3	34	31	28	31	24	22	1	188
Black Redhorse	*Moxostoma duquesnei*	1	2	5	6	14	23	4	1	-	5	61
Golden Redhorse	*Moxostoma erythrurum*	-	1	-	-	-	-	-	-	-	-	1
White Sucker	*Catostomus commersoni*	-	-	-	1	-	-	-	-	-	6	7
Yellow Bullhead	*Ameiurus natalis*	-	-	2	1	-	1	-	1	1	2	8
Stonecat	*Noturus flavus*	-	-	3	-	-	-	-	-	-	-	3
Black Sculpin	*Cottus baileyi*	-	-	-	-	124	-	20	63	106	37	350
Banded Sculpin	*Cottus carolinae*	18	35	41	8	-	-	-	-	-	-	102
Rock Bass	*Ambloplites rupestris*	19	16	9	59	36	18	6	17	45	18	243
Smallmouth Bass	*Micropterus dolomieu*	9	8	12	4	5	8	6	11	6	3	72
Largemouth Bass	*Micropterus salmoides*	-	-	-	1	-	-	-	-	-	3	4
Redbreast Sunfish	*Lepomis auritus*	16	2	4	15	6	18	2	-	-	34	97
Longear Sunfish	*Lepomis megalotis*	1	-	-	-	-	-	-	-	-	-	1
Bluegill	*Lepomis macrochirus*	2	-	-	-	-	1	-	-	-	-	3
Blotchside Logperch	*Percina burtoni*	-	1	-	-	2	-	-	-	-	-	3
Snubnose Darter	*Etheostoma simoterum*	5	3	3	16	34	1	23	27	124	52	288
Greenside Darter	*Etheostoma blennioides*	15	13	3	28	38	3	21	4	7	-	132
Banded Darter	*Etheostoma zonale*	3	-	-	6	9	-	4	-	-	-	22
Redline Darter	*Etheostoma rufilineatum*	40	18	27	74	83	50	48	45	21	15	421
Fantail Darter	*Etheostoma flabellare*	1	-	-	18	41	3	28	69	97	172	429
Number of Specimens		666	553	713	1163	1286	1342	1427	1615	1971	1197	11933
Species Richness		26	19	18	23	21	21	20	19	19	22	36

Table 6. Index of biotic integrity scores on sites sampled on Big Moccasin Creek, Scott and Russell counties, Virginia. Metrics are based on those developed by Karr (1981) and modified by the Tennessee Department of Health and Environmental Conservation (1996) for the Tennessee River Drainage.

	Site									
Metrics	1	2	3	4	5	6	7	8	9	10
Number of native species	3	3	3	3	3	3	3	3	3	5
Number of darter species	5	3	3	5	5	3	5	5	5	5
Number of native sunfish species (less *Micropterus* spp.)	5	1	1	1	1	3	1	1	1	1
Number of sucker species	3	5	3	5	3	3	3	3	1	5
Number of intolerant species	5	3	3	5	5	5	5	5	5	5
Percentage of tolerant species	5	5	5	5	5	5	5	5	5	5
Percentage of individuals as omnivores and stonerollers	1	5	3	1	3	1	1	1	1	1
Percentage of individuals as specialized insectivores	5	5	5	3	5	5	3	3	5	3
Percentage of individuals as piscivores	5	5	3	5	3	1	1	1	3	3
Percentage of individuals as hybrids	5	5	5	5	5	5	5	5	5	5
Percentage of individuals with disease, tumors, fin damage, and other anomalies	5	5	5	5	5	5	3	5	1	5
Catch rate	3	3	3	5	5	5	5	5	5	5
IBI total score	50	48	42	48	48	44	40	42	40	48
Integrity class	Good	Good	Fair	Good	Good	Fair	Fair	Fair	Fair	Good

One of the most useful aspects of the IBI method is its ability to determine trends (Karr et al., 1986). Unfortunately, none of our sampling sites were located exactly at the sites selected by TVA for long-term monitoring. The closest would be their site at RKm 6.1 (Slabtown), which was one kilometer downstream of our site 2. TVA has monitored this site four times between 1994 and 2007. Their scores have ranged from 38 (poor/fair) in 1997 to 46 (fair/good) in 2007 (Matthews & Malone, 2016). Our score of 48 (good) may demonstrate a slight improvement, but during TVA sampling at their Slabtown site in 2012 the score dropped to 42 (fair), and in 2017 declined to 40 (fair) (J.M. Mollish, TVA pers. comm.), which could indicate that ecological health in this system continues to degrade.

BMC continues to contain a rich diversity of freshwater fish species despite demonstrating signs of impairment. Our survey confirmed that 36 of the 42 species previously collected in BMC are still present (Angermeier & Smoger, 1993; Jenkins & Burkhead,

1994). Species known from BMC but not collected by us are Logperch (*Percina capriodes*), Tangerine Darter (*Percina aurantiaca*), Common Carp (*Cyprinus carpio*), Black Bullhead (*Ameiurus melas*), Smallmouth Redhorse (*Moxostoma breviceps*), Green Sunfish (*Lepomis cyanellus*), Gizzard Shad (*Dorosoma cepedianum*), and Creek Chub (*Semotilus atromaculatus*). Common Carp is not native to North America.

Redbreast Sunfish is the only non-native centrarchid collected in our survey. They were first noted in BMC in 1937 by TVA (VDGIF FWIS, 2016) and now are the dominant *Lepomis* in the system. In contrast, the other sunfish species we found, Longear and Bluegill, were quite rare. Bluegill is also stocked heavily for recreational purposes and is widespread in the state (Jenkins & Burkhead, 1994). Longear Sunfish, a species native to the Tennessee River drainage, has become rare (Saylor, pers. obs.), a possible result of pollution and competition from non-native centrarchids. Longear Sunfish are also listed as a Tier IV species, in moderate need of conservation, in Virginia's Wildlife Action Plan (VDGIF, 2015).

Rare species are still extant in BMC despite its impaired nature. Blotchside Logperch is endemic to the Tennessee River drainage and listed as a Tier II species, critical need of conservation action (VDGIF, 2015). Blotchside Logperch was first discovered in BMC in 1993 by Angermeier & Smoger (1993) and our collection of this species at two locations indicates that it is still extant in the system. The Stonecat (*N. flavus*), is a Tier IV species that was first found in BMC by TVA in 1973. Our discovery of three individuals at two locations demonstrates that it is extremely rare but still persists in the system. Fragmentation caused by a lowhead dam located at RKm 7.7 may result in genetic drift and inbreeding depression that could further exacerbate the vulnerability of both species (Waples, 1990).

In 2017, TVA sampling at Slabtown yielded two species new to BMC (J.M. Mollish, TVA pers. comm.). The first was the Spotfin Chub (*Erimonax monachus*), a federally threatened species that is well known from the NFHR (VDGIF FWIS, 2016). The other was Ohio Lamprey (*Ichthyomyzon bdellium*), its nearest recorded previous collection being from the NFHR above Saltville, Smyth County. With their inclusion, the total number of native species in the BMC system is currently 44 of seven families.

Although all of BMC is in need of restoration activities, the most efficient use of limited funding and resources should be directed towards its upper reaches to restrict cattle access and establish riparian buffers along its mainstem and tributaries (VDCR, 2004). To accomplish this task, landowners will need to be informed on the importance of implementing best management practices (Weigmann, 1995). If significant restoration efforts are not focused on BMC, its continued decline will contribute to the loss of species richness and ecological integrity in a waterbody that is critically important to the North Fork Holston drainage.

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An Acoustic Survey of Bats at Radford Army Ammunition Plant's New River Unit, Virginia

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ABSTRACT

White-nose Syndrome (WNS) has caused significant declines in cave bat populations in western Virginia. At the Radford Army Ammunition Plant, New River Unit (Pulaski County, Virginia) pre-WNS bat surveys were minimal and preliminary in nature. Therefore, we completed a large-scale acoustic survey to understand what species of bats occur at the site, and their relative activity. We deployed 12 acoustic detectors at 14 sites for up to 88 nights, May-August 2016. Two automated identification programs recognized 119,600 and 150,391 valid echolocation call files (Kaleidoscope v. 4.0 and EchoClass v. 3.1, respectively). Kaleidoscope identified 60% of bat calls as belonging to the Big Brown Bat (*Eptesicus fuscus*)/Silver-haired Bat (*Lasionycteris noctivagans*) group, 28% as Eastern Red Bat (*Lasiurus borealis*), 5% as *Myotis* species, 3% as Tricolored Bat (*Perimyotis subflavus*), 2% as Hoary Bat (*Lasiurus cinereus*), and 2% as unidentified. EchoClass identified Eastern Red Bat (23%), Big Brown Bat/Silver-haired Bat (21%), Hoary Bat (2%), *Myotis* species (0.2%), and Tricolored Bat (0.3%). Unidentified bat calls represented 53% of call files. We also investigated false-positive identifications of rare species (*Myotis* spp. and Tricolored Bats) in these automated identification programs using manual verification. Calls auto-identified as *Myotis* spp. more often keyed out to Eastern Red Bat, but Tricolored Bat calls appeared to be accurately identified. The apparent misidentification by both programs emphasizes the continued need for visual (manual) confirmation of any *Myotis* spp. calls, coupled with netting efforts at suspect *Myotis* spp. sites. We find sparse evidence of *Myotis* spp. and convincing evidence of Tricolored Bats as a continued presence but in low numbers at the ammunition plant.

Key words: automated identification, EchoClass, false positive, Kaleidoscope, *Myotis*, *Perimyotis.*

INTRODUCTION

White-nose Syndrome (WNS) is a fungal disease that has caused extreme declines in cave-hibernating bat populations in the eastern United States since its discovery in New York in 2006. The current estimate of bat deaths due to the fungus, *Pseudogymnoascus destructans,* exceeds 6 million and it has been confirmed in 31 states (USFWS, 2017). In Virginia, precipitous declines in cave bat populations have been documented since WNS was first detected in the state in 2009 (Powers et al., 2015). For example, Reynolds et al. (2016) reported that summer captures of Northern Long-eared Bats (*Myotis septentrionalis*) in western Virginia declined by 95.1% in 2013 as compared to pre-WNS capture rates. Furthermore, the juvenile capture rate decreased from 40% pre-WNS to <10% in 2013 (Reynolds et al., 2016). Counts from hibernacula conducted in western Virginia in 2013 showed declines of 99.0% for Little Brown Bats (*Myotis lucifugus*), 89.5% for Tricolored Bats (*Perimyotis subflavus*), and 33.5% for Indiana Bats (*Myotis sodalis*) compared to pre-WNS counts (Powers et al., 2015). The persistence of *P. destructans* in Virginia hibernacula suggests

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surveys of summer bat activity will be needed to monitor changes in bat assemblages and improve future management of rare species.

The Radford Army Ammunition Plant, New River Unit (Pulaski County, Virginia) is a military installation in southwestern Virginia that lacked data describing the bat community before WNS. Two nights of preliminary mist net surveys in summer 2012 at the ammunition plant confirmed the presence of Big Brown Bats (*Eptesicus fuscus*), Eastern Red Bats (*Lasiurus borealis*), and Tricolored Bats (Appendix 1). Concurrent acoustic surveys across eight sites additionally identified calls as Hoary Bats (*Lasiurus cinereus*), Silver-haired Bats (*Lasionycteris noctivagans*), and Northern Long-eared Bats (Appendix 1). Following these limited survey efforts, we launched a large-scale acoustic survey of the property in summer 2016. This included the deployment of acoustic detection units across a mosaic of habitat types.

In an environment where cave bat populations have dramatically declined, acoustic techniques are most often used as a "first pass" to detect potential netting sites to confirm (or fail to confirm) the presence of *Myotis* spp. (hereafter, "myotids"; USFWS, 2016a). Although netting is the ideal choice for positively confirming species' presence, short-term netting efforts may not capture all species and therefore falsely suggest absence for some (O'Farrell & Gannon, 1999). Alternately, passive acoustic detectors placed at multiple sites for longer periods can provide increased detection probabilities in areas where WNS has caused declines (Coleman et al., 2014). Ultimately, we chose to first employ acoustic monitoring because our primary goal was to survey for all species of bats, especially rare species, at this military installation.

Following federal surveying guidelines for Indiana Bats (USFWS, 2016a), we utilized two acoustic auto-identification programs, Kaleidoscope v. 4.0 (Wildlife Acoustics, Inc., Concord, MA) and EchoClass v. 3.1 (ERDC, Vicksburg, MS), to assess presence of rare species. *A priori*, we understood that EchoClass is more conservative in its identifications than Kaleidoscope, with the former typically determining more bats calls as unidentifiable. This is likely a combination of pre-set choices made for each program, and acknowledged, inherent variation in call identification between programs (USFWS, 2016b).

As a secondary goal, we compared each acoustic auto-identification program's rate of detection for regionally rare species: all members of the genus *Myotis* and Tricolored Bats. We manually verified all *Myotis* spp. and Tricolored Bat identifications and compared the number of suspected false positives of each program for these calls. There is a long-standing argument about the merits of manual verification versus automated identification software (e.g., varying opinions about call parameters of each species, intraspecific geographic differences in call parameters, observer bias [Betts, 1998]). Multiple researchers suggest that automated programs have particularly limited reliability for identifying rare species and species that have similar calls (Russo & Vaught, 2016; USFWS, 2016b). Therefore, we chose not to rely entirely on automated programs for identification and relative activity calculations of rare species.

MATERIALS AND METHODS

Site Description

The Radford Army Ammunition Plant's New River Unit encompasses 1,142 ha in Pulaski County, Virginia (37°6′6′′N, 80°39′11′′W; datum NAD83). The primary function of this government-owned facility is the storage of military-grade ammunition. A mosaic of habitat types is represented at this site, including grasslands (some fire-maintained, others mowed or established as wildlife food plots), mature forest stands (deciduous, coniferous, mixed), waterbodies (man-made ponds, vernal pools, first-order streams), and buildings (mainly ammunition storage magazines that are partially earth-covered). We selected sites that could attract foraging bats and therefore focused efforts on all bodies of water (permanent or vernal, lentic or lotic; e.g., Grindal et al., 1999; Zimmerman & Glanz, 2000; Francl, 2008), which comprised five sites. We then added a sampling of closed-canopied/late successional (five sites) and open-canopied/early successional habitats (four sites; Table 1).

Field Methods

From 9 May to 5 August 2016 (88 survey nights), we surveyed 14 sites using SMZC and SM4BAT ZC Song Meters (Wildlife Acoustics, Maynard, MA). We spaced sites at least 250 m apart to ensure that individual bats were not sampled on two detectors simultaneously (Ford et al., 2005). Acoustic devices recorded continuously from 1800 h to 0600 h with SMZC units using internal, omnidirectional microphones and SM4BAT ZC units requiring external, directional microphones. We secured detectors mainly on trees or stand-alone PVC poles ca. 2-3 m high to prevent attraction by other wildlife that could disturb equipment. We monitored Song Meter recorders for proper functionality approximately every 2.5 weeks when we replaced batteries. To maximize habitats surveyed and detection of species across the survey, we

Table 1. Fourteen sites acoustically surveyed for bats at the Radford Army Ammunition Plant, New River Unit, Pulaski County, Virginia in summer 2016. Presented are habitat description, grouped habitat types (ES = early successional/open canopied grassland, LS = late successional/closed canopied forest; W = water) and the number of detector nights each site was acoustically surveyed (1 detector for 1 night = 1 detector night). GPS coordinates are available upon request.

Site Name	Habitat Description	Habitat	Detector Nights
Bagging Plant	Concrete building, overlooking open grassland	ES	66
Coyote Creek	First-order stream, open canopy	W	46
Dirt Road	Primitive gravel road through closed-canopied mature pines	LS	46
EPFU Alley	Paved road lined with mature mixed forest	LS	88
Fishing Pond	0.2-ha pond	W	66
Food Plot	VA. Dept. of Game & Inland Fisheries food plot	ES	23
Ginseng Hollow	Mowed grassy plot surrounded by mature forest	LS	88
Hibernaculum	Grass-covered storage building	ES	66
Ignitor	Concrete wall structures. scattered mature pines	LS	35
Pond 2	0.2-ha pond	W	88
Pwamp	0.8-ha pond/swamp	W	88
Road S of Hazel Hollow	Open, shrubby grassland	ES	66
Vernal Pool	Vernal pool/grassland surrounded by mature deciduous forest	W	88
White Pines	Primitive gravel road through mature pines	LS	18

moved individual detectors that had recorded negligible bat activity in the previous 2.5-week monitoring period; for this reason, we sampled sites for 18-88 detector nights (1 detector set for 1 night = 1 detector night) per site.

Acoustic Analysis

We initially employed the automated programs Kaleidoscope and EchoClass to identify bat call files. For Kaleidoscope, we set parameters to identify calls from 16-120 kHz, with a minimum number of three call pulses, and selected nine known species in the region from Kaleidoscope's classifier version 3.1.0 (Big Brown Bat, Silver-haired Bat, Eastern Red Bat, Hoary Bat, Indiana Bat, Northern Long-eared Bat, Little Brown Bat, Eastern Small-footed Bat [*Myotis leibii*], and Tricolored Bat). Sensitivity was set at a more liberal level (-1), following a similar regional study by Austin (2017). In EchoClass, we selected species Set 2, which included the same species selected in Kaleidoscope. Sensitivity levels are predetermined in this program. In AnalookW software version 4.1t (Corben, 2015), using a standard noise filter (Clement et al., 2014), H. Custer manually vetted all myotid and Tricolored Bat calls detected by both programs, searching for false positives. Further analysis of all calls recorded from two randomly-selected sites

(Fishing Pond and Hibernaculum [Table 1]) were manually vetted by K. Powers to seek out additional myotids and Tricolored Bat species (false negatives). We used dichotomous keys (M. A. Menzel, S. Owen, and J. B. Johnson, West Virginia University, unpubl. data) and classification trees (A. Silvis, Virginia Tech, unpubl. data) to detect calls that were, with author certainty, false positives or false negatives. Furthermore, due to a recognized overlap in call signatures, we grouped Big Brown Bat and Silver-haired Bat identifications into one species group in our results (Betts, 1998; Austin, 2017). After re-assigning false positives and false negatives to what we considered to be the correct species identification, we calculated each program's identification accuracy for myotids and Tricolored Bats.

RESULTS

Both automated identification programs categorized at least some calls as belonging to each of the nine bat species we had selected as *a priori* possibilities. The 872 detector nights included 376 at sites with water, 275 at late-successional sites, and 221 at early-successional sites. Across all detector-nights, Kaleidoscope recognized 119,600 bat call files whereas EchoClass recognized 150,391 (Table 2). Both programs determined that Big Brown Bat/Silver-haired Bat and Eastern Red Bat were most commonly detected (Table 2), together comprising 44% (EchoClass) to 88% (Kaleidoscope) of all calls. If unidentifiable bat calls were removed, the combined percentages of these three species (90.0% for Kaleidoscope, 94.4% for EchoClass) were comparable.

We discovered a stark contrast in *Myotis* spp. calls identified by the two programs. Kaleidoscope identified 5,975 call files as *Myotis* (5% of all identified bat files), but our manual vetting suggested that >99% of these were Eastern Red Bat calls. EchoClass was much more conservative in its *Myotis* identifications, with only 367 call files, but 89.1% of these were likely Eastern Red Bat calls (Table 2). After manual verification, *Myotis* spp. calls comprised <0.1% of all calls for both programs, and calls were not concentrated in any particular habitat type on the property. Although not presented in Table 2, more than one-third of identified

Table 2. Number of call files per species, as identified from acoustic surveys of bats at Radford Army Ammunition Plant, New River Unit, Pulaski County, Virginia in summer 2016. Presented are species detected by the automated identification programs Kaleidoscope and EchoClass ("Original"), and results after manual vetting of *Perimyotis subflavus* (Tricolored Bat) and *Myotis* species ("Modified") with relative proportion of calls by species (percentage, in parentheses). Calls listed as "No ID" were recognized as bat calls but were further unidentifiable by the automated programs or manual vetting. Reductions in the number of Total, Modified calls compared to Total, Original calls are due to additional "noise" files being erroneously identified as bat calls.

	Kaleidoscope		EchoClass	
Species	Original	Modified	Original	Modified
E. fuscus/L. noctivagans	72,072 (60%)	72,097 (61%)	31,718 (21%)	28,845 (20%)
Lasiurus borealis	33,892 (28%)	40,510 (34%)	35,086 (23%)	35,419 (24%)
Lasiurus cinereus	2,546 (2%)	2,547 (2%)	3,083 (2%)	3,085 (2%)
Myotis spp.	5,975 (5%)	45 (<0.1%)	367 (0.2%)	40 (<0.1%)
Perimyotis subflavus	3,282 (3%)	1,992 (2%)	487 (0.3%)	443 (0.3%)
"No ID"	1,833 (2%)	1,961 (2%)	79,650 (53%)	79,681 (54%)
Total	119,600	119,152	150,391	147,513

Myotis calls keyed out to that of *M. leibii*. After manual vetting, we recognized myotids at eight of the 14 sites, and the total number of calls was <0.05 call sequences per detector night for any *Myotis* species across the entire survey period.

We classified call sequences as Tricolored Bats at 13 of the 14 survey sites, with generally higher call volume at permanent open-water sites (primarily at Fishing Pond, Table 1). After manual vetting, total number of Tricolored Bat calls were 0.5 and 3.7 call sequences per detector night for EchoClass and Kaleidoscope, respectively. Kaleidoscope appeared to correctly categorize 60% of Tricolored Bat calls, and EchoClass correctly classified 91% of these calls. Calls misidentified as Tricolored Bat better fit the parameters of Eastern Red Bat.

Our searches for false negatives did not reveal extreme cases of misidentification. For example, manual vetting of >70,000 calls from one open water site (Fishing Pond) detected 15 additional calls of *M. leibii*. However, because these 15 calls had been correctly identified to the genus *Myotis* by both programs, they did not alter our grouped myotid trends (Table 2). No additional Tricolored Bat calls were recognized in an examination of these calls.

DISCUSSION

The bat species that had been previously confirmed via mist-netting and detected through acoustic techniques in 2012 were all identified in our 2016 acoustic surveys (Appendix 1). Not surprisingly, Big Brown Bat/Silver-haired Bat and Eastern Red Bat were the most commonly-detected species. Although both automated identification programs recognized unusually high detections of Silver-haired Bat calls (which we grouped with Big Brown Bat), this species typically is caught only in May when it migrates through Virginia (Cryan, 2003; Powers, pers. obs.). It is likely that nearly all autoclassified Silver-haired Bat calls are actually those of Big Brown Bats (Betts, 1998).

The presumed near-absence of Little Brown Bats, Northern Long-eared Bats, and Indiana Bats was expected, given their federal or state listings and documented rarity on the landscape in western Virginia (Powers et al., 2015; Reynolds et al., 2016; Austin, 2017). The presumed presence of Eastern Small-footed Bats is not entirely surprising; we suspect that they use cliff faces and other vertical exposures along the New River (ca. 4.5 km E of the ammunition plant) as day roosts, and may forage at the study site. Netting efforts would be required to confirm their presence.

Despite state-listed Tricolored Bats being nearly ubiquitous across our 14 sites, the number of call sequences recorded at any given site was relatively low. Based on 2012 captures at Fishing Pond (Appendix 1), coupled with manual vetting of several hundred Tricolored Bat calls at this site in 2016, we confirm their continued presence with some confidence. The Radford Army Ammunition Plant has several characteristics that may explain why Tricolored Bats may be present and more abundant than myotids on the property. Forest successional stages vary widely across the property, and all stages are within 1 km of at least one of the open water sites on the property, providing the bats' preferred foraging habitat (Center for Biological Diversity and Defenders of Wildlife, 2016). Given that Tricolored Bat roost selection varies by female reproductive stage (Veilleux et al., 2004), the variety of open- and closed-canopied habitats may be an attractive feature of the property. We suggest further netting efforts to confirm the continued presence of Tricolored Bats and identify habitat features at the ammunition site that are relatively important for this species.

Our acoustic survey results mirror those of other regional acoustic surveys conducted after the onset of WNS. Austin (2017) also surveyed bats in the central Appalachian highlands in summer 2015 and 2016, and found a similar species composition, and proportionally similar dominant species. Small-bodied species like Tricolored Bats and myotids also were poorly represented on the landscape. Although published acoustic surveys in Virginia prior to the onset of WNS are scarce, other regional surveys around the advent of WNS noted declines in particular species of *Myotis* (Dzal et al., 2011; Reynolds et al., 2016) and in Tricolored Bats (Dzal et al., 2011) during summer months.

Although our acoustic survey was intended as a first step in assessing the structure of this WNS-affected environment, the frequent misidentifications made by automated programs could have negatively affected management of bat populations (Russo & Vaught, 2016). In this case, the over-identification of *Myotis* spp. at the ammunition plant might have led to resource allocations that could or should have been used for other rare animal or plant species with a confirmed presence (Ford, 2014). Identification of acoustic calls will always have some degree of subjectivity. The overlap in call characteristics among bat species and the influence of habitat clutter on calls during foraging activities has been well documented (e.g., Wund, 2006). Therefore, we support continued manual vetting of all *Myotis* calls (USFWS, 2016b).

A management goal of the Radford Army Ammunition Plant is to monitor rare species; our acoustic surveys provide a springboard for future combined acoustics and netting projects. Surveys should focus on netting locations with the highest detection rates for Tricolored Bat (particularly Fishing Pond) and *Myotis* spp. to confirm their (continued) presence on the military installation. If netting and subsequent radiotelemetry efforts successfully document Tricolored Bat or *Myotis* spp. maternity roosts or bachelor colonies on the property, these data would contribute to the Best Management Practices already in place on the property.

ACKNOWLEDGEMENTS

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Appendix 1. Number of call files per species, as identified from acoustic surveys of bats at Radford Army Ammunition Plant, New River Unit, Pulaski County, Virginia in summer 2012. Call results assessed by EchoClass v. 3.1, and calls identified as *Myotis* spp. or *Perimyotis subflavus* were manually vetted by K. Powers. After vetting all *Myotis* spp. calls, only *M. septentrionalis* remained. Calls listed as "No ID" were recognized as bat calls but were further unidentifiable by the automated programs or manual vetting. Four sites with (*) were included in 2016 project; remaining four sites were open-canopied sites not selected for continued surveys. GPS coordinates are available upon request. Superscript ([1]) indicates individuals of this species were captured in concurrent mistnetting efforts.

Species	Bagging Plant*	EPFU Alley*	Fishing Pond*	Pwamp*	Maga-zine 1521	Maga-zine 1523	Maga-zine 1618	Pole Barn	TOTAL
E. fuscus[1]/*L. noctivagans*	2	23	146	49		1	5		226
Lasiurus borealis[1]	2	18	58	31		1	7		117
Lasiurus cinereus		1		11		2		1	15
Myotis septentrionalis							1		1
Perimyotis subflavus[1]			41	1					42
"No ID"	4	40	108	139	1	8	22	1	323

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Old Collections Add a New Species to Virginia's Ensign Wasp (Hymenoptera: Evaniidae) Fauna

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ABSTRACT

Evania appendigaster (L.), an egg predator of household cockroaches, is newly recorded for the fauna of Virginia based on an 80-year-old specimen at the Virginia Museum of Natural History. With the inclusion of this species all seven eastern evaniid taxa are now known to occur in the state. This finding is further evidence for the value of research collections in documenting the world's biodiversity.

Key words: *Evania appendigaster*, cockroach egg predators, new state record, eastern US, research collections.

INTRODUCTION

Evaniids (Hymenoptera: Evaniidae) are a small group of egg predators on cockroaches (Dictyoptera: Blattodea). Females oviposit in the ootheca (egg case) and the immature stages develop as solitary predators consuming the eggs. There are surprisingly few host records for the group, but known associations suggest that each evaniid species specializes on egg cases of a particular size, rather than on those of (a) particular host taxon/taxa (Townes, 1949; Roth & Willis, 1960; Deyrup & Atkinson, 1993).

The adults are small to medium-sized dark colored wasps that are readily distinguished by the small and strongly laterally compressed metasoma. The group is common across the world but reaches its highest diversity in the warm, humid environments of the lower latitudes where their hosts abound. The family contains approximately 580 described species in 21 extant genera (Deans, 2005; Mullins et al., 2012). This predominantly tropical group is represented in the Nearctic Region (north of Mexico) by eleven species belonging to four genera: *Evania* (1 sp.), *Prosevania* (1 sp.), *Evaniella* (3 spp.), and *Hyptia* (6 spp.) (Townes, 1949; Deans, 2005). To date, seven species have been recorded from the eastern part of the continent (Townes, 1949; Smith, 1998). These include two introduced egg predators (*Evania appendigaster* [Linnaeus, 1758] and *Prosevania fuscipes* [Illiger, 1807]) of domestic cockroaches, and five native taxa (*Evaniella semaeoda* Bradley, 1908, *Hyptia floridana* Ashmead, 1901, *H. harpyoides* Bradley, 1908, *H. reticulata* [Say, 1836], and *H. thoracica* [Blanchard, 1840]) which use egg cases of cockroaches in the genera *Parcoblatta*, *Ischnoptera*, *Cariblatta*, and possibly other wood cockroaches (Blattodea: Ectobiidae) found in the eastern forests (Deyrup & Atkinson, 1993).

The evaniid fauna of the mid-Atlantic states (Delaware, District of Columbia, Maryland, West Virginia, and Virginia) was reviewed recently by Smith (1998, 2011), who reported all seven eastern species from the area. Of these, only the non-native *E. appendigaster* did not appear on the Virginia list.

MATERIALS

While curating uncatalogued specimens at the Virginia Museum of Natural History (VMNH), I encountered a single male *E. appendigaster* which represents the first known Virginia record of this species. The specimen (VMNH accession # 1991-084), collected in 1937, remains in good condition lacking only the two terminal segments of the left antenna, the hind tarsi, and the right hind tibia (Fig. 1). It bears two labels: 1) top label is handwritten and reads "Richmond Dairy Co."; 2) bottom label is printed, with collector's name and date

Fig. 1. *Evania appendigaster* (Richmond, VA) lateral view, forewing length 5.8 mm.

handwritten, and reads "R. Murrill U. of Richmond, Va. 15 x 1937."

Review of associated documentation revealed that the specimen was originally part of the University of Richmond student insect collection. The entire collection was acquired by, and transferred to, VMNH in 1991 along with approximately 22,000 other pinned insects. Although the Richmond Dairy Company ceased operation in 1970, the building where the specimen was collected still exists at its original location near downtown Richmond at approximately N37.54752º, W077.44370º.

RECOGNITION

Members of *Evania* are characterized by their larger size, elongated hind legs, widely separated middle and hind coxae, and by their somewhat flattened faces (Deans & Huben, 2003). As currently understood, the group comprises 66 valid species (33 confirmed and 33 *incertae sedis*) with a worldwide distribution (Deans, 2005).

The relatively large size (forewing length 5.5-7.0 mm) of *E. appendigaster* will readily separate it from all other Nearctic forms (forewing length $\leq$ 5.0 mm), with the exception of *P. fuscipes*. From the latter it can be distinguished by a number of features: 1) wide separation of the middle and hind coxae with the distance approximately twice the length of the middle coxa; this distance is subequal to the length of the middle coxa in *P. fuscipes*; 2) rounded pronotal shoulders which lack a sharp transverse ridge; 3) smooth face with fine, sparse punctures as opposed to a coarsely striato-punctate face; and 4) pleura with sparse, separate punctures rather than close, reticulate punctures.

Keys to the Nearctic species of Evaniidae can be found in Townes (1949) and for the eastern fauna in Smith (1998).

DISCUSSION

Based on specimens from Washington, D.C., the presence of this wide-ranging species in Virginia was expected (Smith, 2011) but, to date, no specimens have been available for study despite intensive collecting in the area (Smith, 1998, 2011). With the inclusion of this species all seven eastern evaniid taxa are now known to occur in the state.

As with many other introduced species, *E. appendigaster* presumably was transferred, along with its hosts, to new areas via human commerce. It is one of the world's most widely distributed evaniids and now is nearly cosmopolitan. It occurs in most tropical and subtropical areas with its known range extending farther into the Palearctic and Nearctic regions (Deans, 2005). The origin of *E. appendigaster* is not known but, based on the diversity and distribution of closely related *Evania* species, Townes (1949) argued that it originated in the Oriental Region.

Evania appendigaster is the less common of the two introduced species that have become established in North America (Smith, 1998). The earliest known United States (and North American) record of this species is a specimen collected in Washington, D. C. in June 1879 (Townes, 1949). It has been reported subsequently from Alabama, Arizona, California, Florida, Georgia, Hawaii, Louisiana, Massachusetts, Missouri, New Mexico, New York, Ohio, Pennsylvania, South Carolina, Tennessee, and Texas (Swezey, 1929; Townes, 1949; Smith, 1998; Gulmahamad, 2007; Bug Guide, 2017). In the United States, this species is exclusively associated with urban areas where its hosts are found (Townes, 1949; Smith, 1998; Deans, 2005). Although it is more commonly found in the Atlantic and Gulf Coast states, it is very likely that this species occurs in all major urban centers across the country. Where they occur, these wasps are occasionally seen on the windows of city buildings and people's homes.

In different parts of the world, this species is a well-known egg predator of household cockroaches which produce larger oothecae, particularly *Blatta orientalis* Linnaeus, 1758, *Periplaneta americana* (Linnaeus, 1758), *P. australasiae* Fabricius, 1775 (Townes, 1949; Stange, 1978), and possibly *Melanozosteria soror* (Brunner von Wattenwyl, 1865) and *Neostylopyga rhombifolia* (Stoll, 1813) (Swezey, 1929). Detailed natural history information, including oviposition behavior and development, can be found in Haber

(1920), Cameron (1957), and Roth & Willis (1960). The potential of this species as a biocontrol agent of the American cockroach, *P. americana*, was reviewed by Fox & Bressan-Nascimento (2006).

The finding of *E. appendigaster* among materials at the VMNH is further testament to the important role of research collections for the study of the world's biodiversity. The specimen was collected eighty years ago but the presence of this species in Virginia went undocumented until now. Museum, university, and private collections provide indispensable documentation of the world's flora and fauna, their environment, biological associations, and the changes in their distribution through both space and time (Suarez & Tsutsui, 2004).

Since the time it was acquired by the VMNH, the now defunct University of Richmond student insect collection has provided materials forming the bases of at least nine scientific publications (Hoffman, 1992, 1994, 2006, 2012; Smith, 2006; Evans & Flint, 2009; Bedell, 2010; Hoffman & Roble, 2012; Roble & Hoffman, 2012). These publications range from single species accounts to detailed regional studies of higher taxa, and have produced at least four new state records and associated distributional and biological information for eleven families in six insect orders. Without the long-term support and funding of these collections, the information and knowledge they can provide undoubtedly will be lost. This is especially relevant in the current era of fast environmental change. In the future, research collections will become increasingly important in providing the bases for understanding how such changes affect extant (or recently extinct) taxa.

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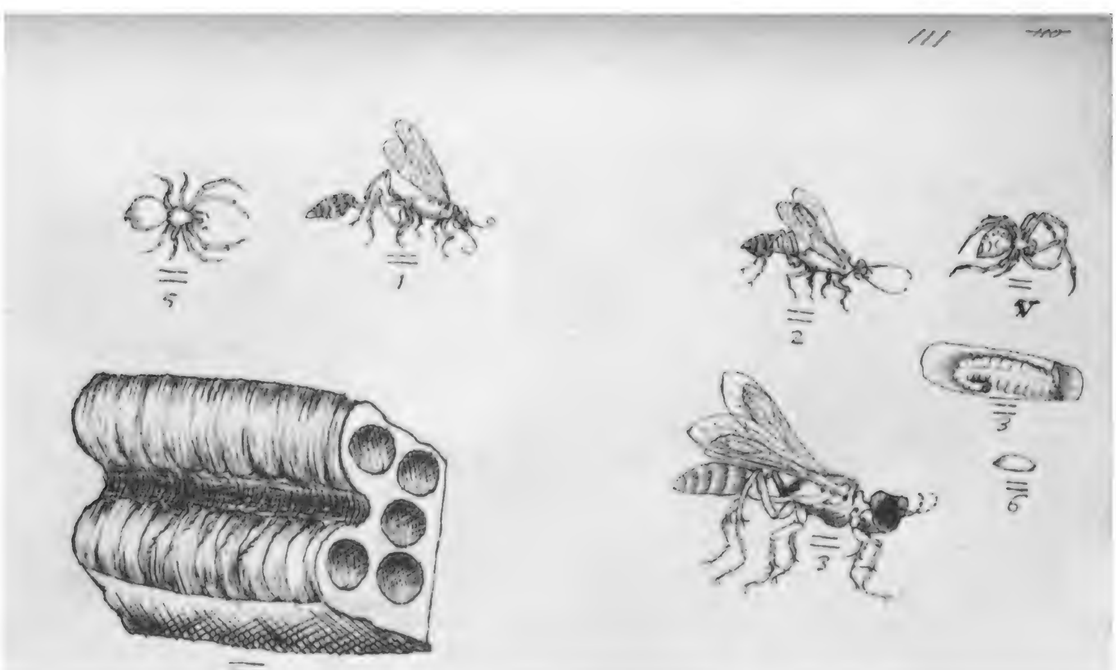


Original drawings by John Banister

Miscellanea

Reports

1. Minutes of the Executive Committee of the Virginia Natural History Society Meeting of December 2, 2017

The 2017 meeting of the Executive Committee of the Virginia Natural History Society was called to order by President Al Gardner at 1:00 PM on December 2, 2017 in Settle Hall at Hampden-Sydney College, Hampden-Sydney, Virginia. In attendance were Alfred Gardner, Ralph Eckerlin, Rachel Goodman, Kal Ivanov, Michael Lachance, Paul Marek, Chris Milensky, Nancy Moncrief, and Steve Roble.

Nancy Moncrief updated the council that she contacted people with lapsed memberships to encourage them to renew. Rachel Goodman noted that the membership of VNHS went from 68 (including institutions) before this in November to 75 as of today. This led to discussion of the Secretary/Treasurer's report. The current bank account is $15,787. Steve Roble mentioned the free one-year student memberships, intended as an incentive to recruit and support younger members; only a couple people have applied for / used it. Members suggested that this opportunity should be worked up in a notice to be advertised at VAS meetings and in additional academic venues. Moncrief agreed to take on this responsibility.

Paul Marek reported that there has not been a recent VNHS newsletter due to other work commitments. He is working one up to be distributed in January.

Steve Roble presented the Editor's report. *Banisteria* No. 48 was published at the end of November, and No. 49 will be published in late January/early February. Contents for *Banisteria* issues No. 50 and No. 51 (to be published in 2018) were presented, including a possible article on the history of John Banister for the silver anniversary of the journal. Transition of the journal to a new editor, Todd Fredericksen, will commence with issue No. 52 in 2019.

The Council discussed upcoming changes in VNHS Council membership. Rachel Goodman is beginning a step down in Secretary/Treasurer duties and will transfer the inventory of journals, digital files, and bank accounts over the coming year. The council passed a motion to amend the bylaws to separate the position of Secretary-Treasurer into two positions, Secretary and Treasurer. Paul Marek was nominated for the newly created office of Secretary, and he was elected unanimously to serve through 2021. Rachel Goodman will continue to serve as Treasurer for the coming year.

Potential nominees for the vacant Councilor position were discussed. The Secretary (Marek) will solicit additional nominations from the society via email. Ballots will be distributed with the next issue of *Banisteria*, along with the dues renewal forms.

Roble presented the current status of the VNHS website after noting that Webmaster John White had resigned in October. Roble will pay all the fees associated with renewing and maintaining the website for one year. Marek will serve as the new Webmaster and will research alternative web hosting possibilities with better fees and services during the coming year.

The Biodiversity Heritage Library (BHL) has requested the listing of *Banisteria* past issues in its site as Creative commons content for non-commercial use. The Council agreed to list articles with BHL, but embargo those articles published within the past two years. EBSCO is now storing and distributing the content of *Banisteria* online, as of the end of 2017 (including the most recently published articles). Note that EBSCO will not have (and does not want) any issues of *Banisteria* published before 2017. Also, *Banisteria* is associated with Zoological Record, although this only carries a subset of the journal's publications.

John White will be thanked formally for his 16-year service as Webmaster via a letter from President Gardner and will receive a lifetime membership.

Members discussed the role of the society and ways of encouraging participation. Moncrief suggested creating an online survey of members, possibly connecting with the Virginia Master Naturalists, and possibly having a meeting at the Virginia Museum of Natural History in Martinsville for the general members.

The meeting adjourned at 2:55 PM.

Respectfully submitted,
Rachel Goodman, Treasurer

2. Webmaster's Report

Traffic on the society's website during 2017 is summarized in the following table:

Month	**Visits**	**Pages**	**Files**	**Hits**
Dec-17	1987	3052	6525	14649
Nov-17	2289	3401	7373	15637
Oct-17	2117	3390	6999	14545
Sep-17	2189	3522	8404	16464
Aug-17	2056	3246	9111	16686
Jul-17	1981	3430	7962	14591
Jun-17	1795	3168	7990	14590
May-17	1802	3061	7549	14271
Apr-17	1782	3104	7206	13658
Mar-17	1877	3458	7250	13802
Feb-17	1531	3019	7524	11998
Jan-17	1757	3492	9289	13379
Totals	23163	39343	93182	174270

Respectfully submitted,
Paul Marek, Webmaster

3. Editor's Report

The Virginia Natural History Society recently entered into an agreement with the Biodiversity Heritage Library (BHL) consortium to make digital copies of *Banisteria* issues more than 2 years old freely available on their website (https://www.biodiversitylibrary.org/). BHL is "a consortium of natural history and botanical libraries that cooperate to digitize the legacy literature of biodiversity held in their collections and to make that literature available for open access and responsible use as a part of a global 'biodiversity commons.' " The BHL website currently contains more than 133,000 titles, 220,000 volumes, and 53.8 million pages. BHL also serves as the literature component of the Encyclopedia of Life project. In addition to our recent agreement with EBSCO, the BHL collaboration should help to make *Banisteria* and its contents more widely known to scientists, naturalists, students, and the general public worldwide.

I am currently working on the first issue of *Banisteria* for 2018. More submissions are always needed for future issues of this journal because there is rarely a backlog of accepted manuscripts, so please consider submitting a paper, note, biography, or historical contribution concerning the natural history of Virginia. Consult the Instructions for Authors page posted on the society's website before preparing your paper.

Respectfully submitted,
Steve Roble
Editor, *Banisteria*

Announcements

1. Dues renewal and election ballot

A membership renewal form and election ballot are enclosed with this issue of *Banisteria*. If you have not already done so, please renew your membership for 2018 by returning the form and payment by check or money order. All members are encouraged to recruit at least one new member to the society. Faculty members may nominate up to three students for a free one-year membership (see Student Membership Incentive below).

Please cast your vote for the vacant Councilor position by returning the enclosed ballot prior to the due date.

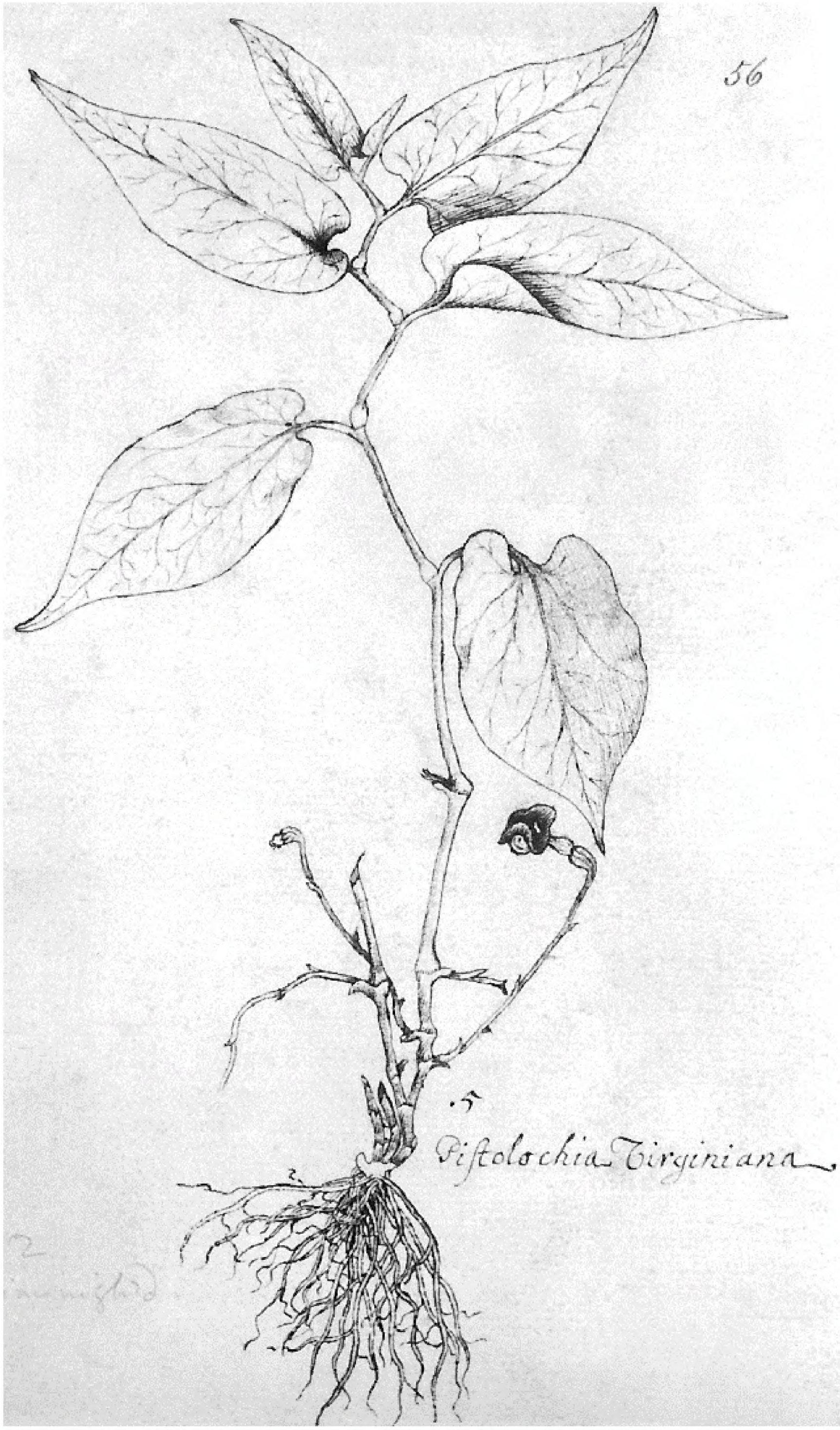
2. Virginia Natural History Society – General Members Meeting

Please "Save the Date" for a general members meeting of the Virginia Natural History Society on 13 October 2018 at the Virginia Museum of Natural History in Martinsville. More details will follow, but we anticipate a program of invited and contributed talks (approximately 15 minutes each) and posters.

3. Student Member Incentive

The Virginia Natural History Society is offering free one-year memberships for students (high school, undergraduate, or graduate) nominated by an advisor/teacher/mentor who is a member in good standing of the Society. This offer is available for up to 20 students each year, and nominations will be considered in the order in which they are received.

Nominators should include the following information for up to three students: name, institution, enrollment level, mailing address, e-mail address, and a short paragraph describing the student's interests in and activities related to Virginia natural history. Nominations should be sent to the Chair of the membership committee, Nancy Moncrief at nancy.moncrief@vmnh.virginia.gov and the Treasurer, Rachel Goodman at rgoodman@hsc.edu.



Endodeca serpentaria (L.) Raf.
Virginia Snakeroot or Turpentine-root

Original drawing by John Banister, sent to Bishop D. H. Compton in 1689.
Figure 56 in folio in Sir Hans Sloane's MS 4002 in the British Museum.
Photocopy courtesy of Joseph and Nesta Ewan.

Virginia Natural History Society

http://virginianaturalhistorysociety.com/

General Information

The Virginia Natural History Society (VNHS) was formed in 1992 to bring together persons interested in the natural history of the Commonwealth of Virginia. The VNHS defines natural history in a broad sense, from the study of plants, animals, and other organisms to the geology and ecology of the state, to the natural history of the native people who inhabit it. The goals of the VNHS are to promote research on the natural history of Virginia, educate the citizens of the Commonwealth on natural history topics, and to encourage the conservation of natural resources.

Dissemination of natural history information occurs through publication of the journal *Banisteria*, named for John Banister (1650-1692) who was the first university-trained naturalist to work in Virginia. The first issue was published in 1992, and the journal is published twice per year in spring and fall. Articles cover a wide array of subjects, and prospective authors are encouraged to submit manuscripts on any aspect of natural history in Virginia; papers may pertain to Virginia or regional archaeology, anthropology, botany, ecology, zoology, paleontology, geology, geography, or climatology. Biographies, obituaries, and historical accounts of relevance to natural history in Virginia also are welcomed. Manuscripts are peer-reviewed for suitability and edited for inclusion in the journal.

Page charges ($20/page) are waived if the sole or first author is a VNHS member. All authors must pay $75/page if they desire color printing of figures. The society's website contains detailed instructions for prospective authors and PDF reprints of all *Banisteria* articles that are more than two years old.

Memberships

The VNHS is open to anyone with an interest in natural history and welcomes participation by all members in society activities and efforts to promote education and conservation. Membership includes a subscription to *Banisteria* and invitations to periodic symposia and field events. Annual dues for members are $20 (per calendar year); library subscriptions are $40 per year. Checks or money orders should be sent to the Treasurer, who also has most back issues of *Banisteria* available for sale. The VNHS is a tax-exempt, nonprofit, society under Section 501(C)3 of the IRS. We welcome donations to support our mission in Virginia.

Virginia Natural History Society

Application for Membership

Name ______________________________

Address______________________________

____

____

Zip Code ___________________________

Phone ______________________________

Email ______________________________

Area(s) of Interest _______________________

ANNUAL DUES AND SUBSCRIPTIONS TO *BANISTERIA*

(memberships and subscriptions are by calendar year; subscribers/members outside the United States should add $3.00 for additional postage)

- ☐ $500.00 Life (not annual)
- ☐ $300.00 Benefactor
- ☐ $100.00 Patron
- ☐ $50.00 Supporting
- ☐ $40.00 Institutional
- ☐ $25.00 Family
- ☐ $20.00 Regular
- ☐ $5.00 Student (see below)
- ☐ I have added a contribution of $______ to my membership dues.

The special student rate is applicable only when accompanied by the following certification signed by a faculty advisor (**students are also eligible for a 1-year free membership** if an advisor's nomination is approved by the society's Executive Committee; see nomination guidelines in *Banisteria*).

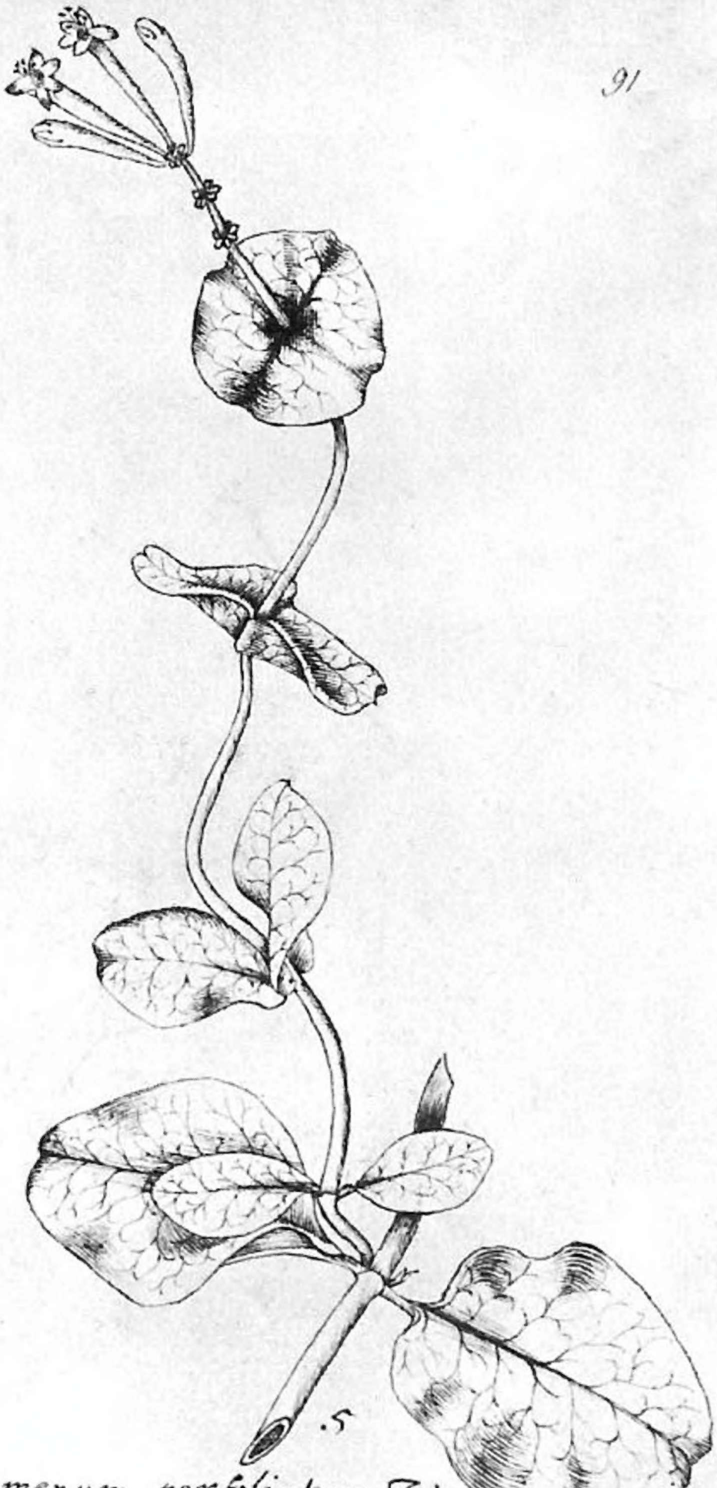
Institution ___________________________

Advisor ______________________________

Date_________________________________

Make checks or money orders payable to:
Virginia Natural History Society

Send membership form and dues to:
Dr. Rachel Goodman, Treasurer
Virginia Natural History Society
Box 74
Hampden-Sydney, VA 23943



Periclymenum perfoliatum Virginianum sempervirens & florens